Ablative thermal protection systems for entry in Mars atmosphere.
A presentation of materials solutions and testing capabilities

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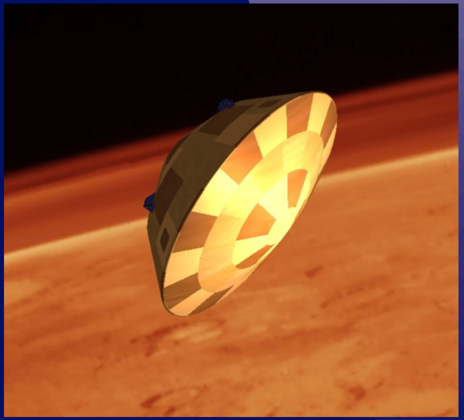
Prepared for

4th International Planetary Probe Workshop
Pasadena, CA, USA June 27-30, 2006

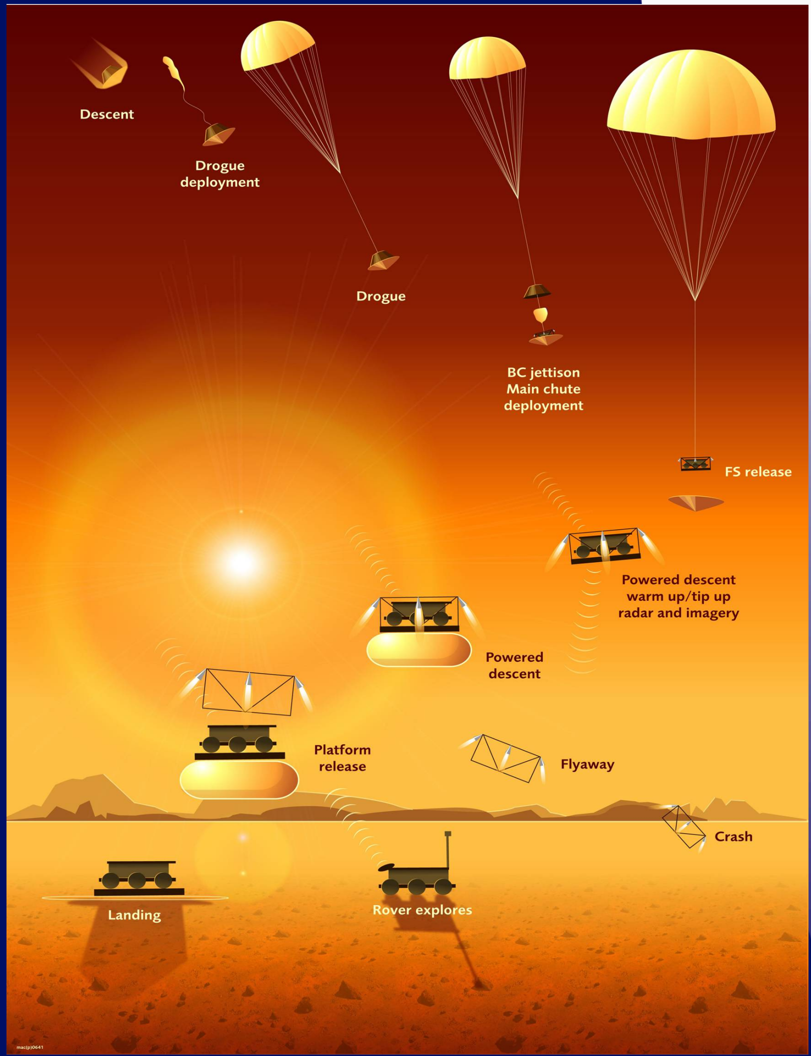


Presentation Outline

- ExoMars mission overview
- ExoMars Descent Module
- Norcoat-Liege
  - Composition and manufacturing
  - Heritage
- Qualification for Mars Missions
- Test facilities
- Modeling
- Norcoat Liege preferred to Alternative Solutions
- Growth potential
- Conclusion

ExoMars Mission Overview

- Launch in 2011 (backup 2013)
- Carrier Module will release Descent Module
- Payloads to land on the surface
  - Rover + Pasteur Payload for exobiology and geological research
  - Geophysics/Environment Package (GEP) for Martian geophysics and ambient conditions



from ASTRIUM / EADS-ST phase A study

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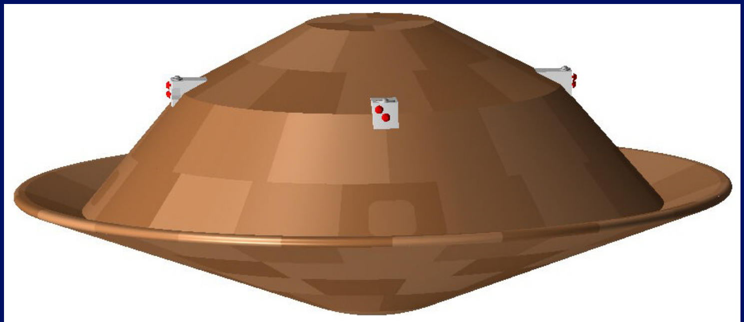
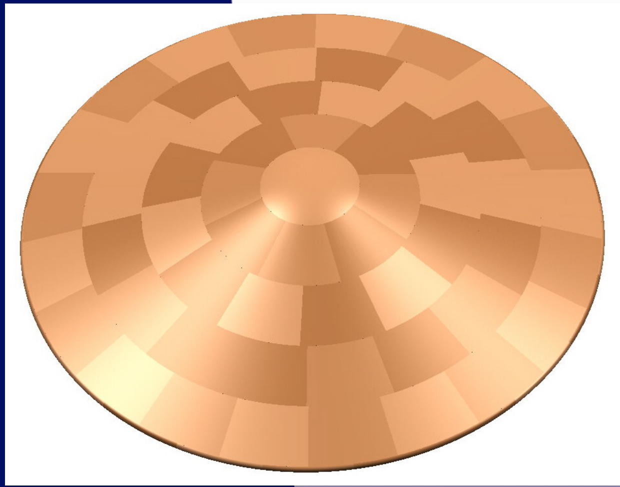
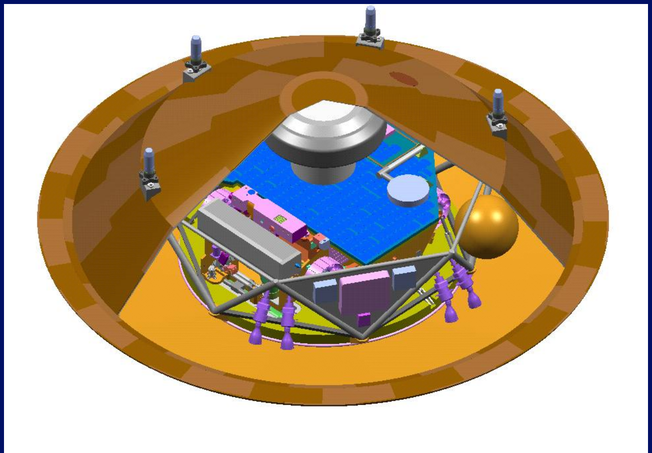
ExoMars Descent Module : Main features (from ASTRIUM / EADS-ST phase A study)







- ~ 3.80 m diameter
- ~ 1200 kg
- TPS = Norcoat-Liege on Frontshield & Back-Cover
- Frontshield 180 kg
  (TP ~50%)
  60 large panels 10 mm
  + 50 small panels 6 mm
- Back-Cover 180 kg
  (TP ~25%)
  80 panels 6 mm

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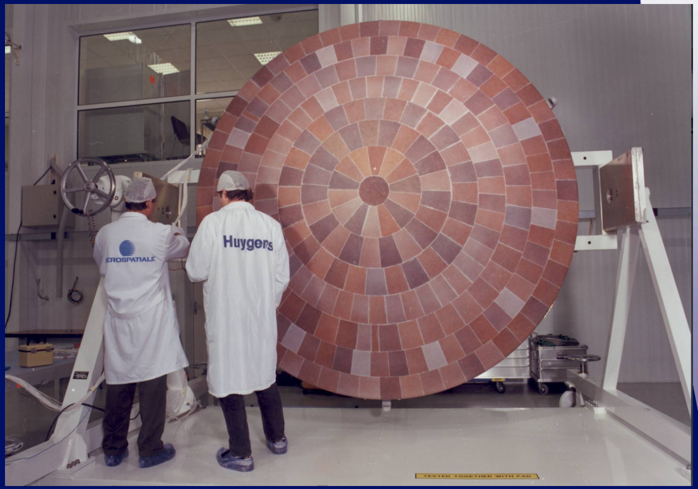
TPS trade-off
Norcoat Liege preferred to Alternative Solutions

- AQ60
  - low density silica / phenolic material used for Huygens heatshield
  - Norcoat-Liege allows a simpler design, an easier implementation and a slightly lower mass budget
- PICSIL
  - low density silicone-based ablator baseline for European CTV studies. (1995-96)
  - less optimized than Norcoat-Liege for a mission to Mars, due to the lower thermal solicitations
  - higher maturity of Norcoat-Liege



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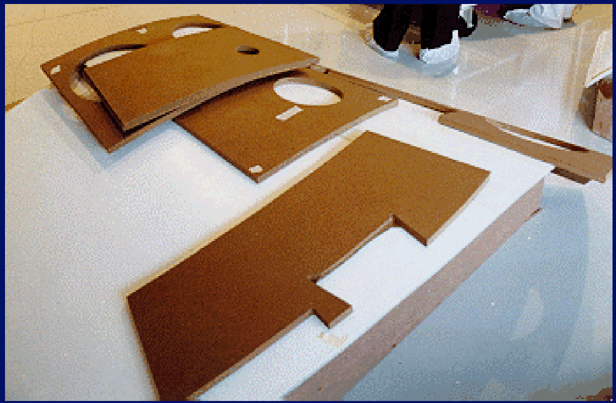
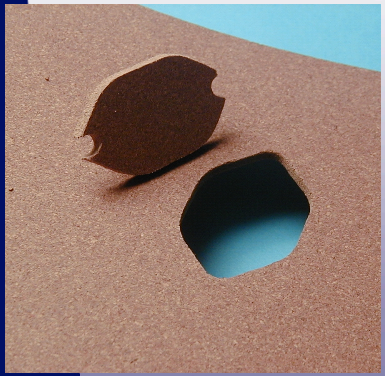
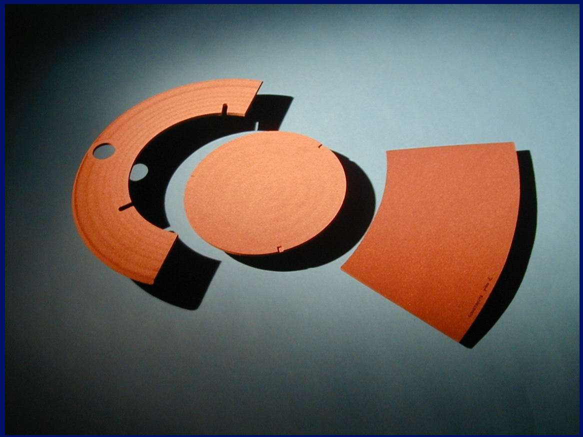
NORCOAT® LIEGE
Composition and manufacturing

PROCESS SUMMARY

- Realization of panels in an heated press by cork powder agglomeration
- Cutting, machining and forming
- Bonding under pressure on the equipment
- Possibility of outgassing treatment for space applications
- Applicable on developable or not very complex surfaces




CHARACTERISTICS

- Density: 0.47
- Thickness: from 1.5 to 150 mm

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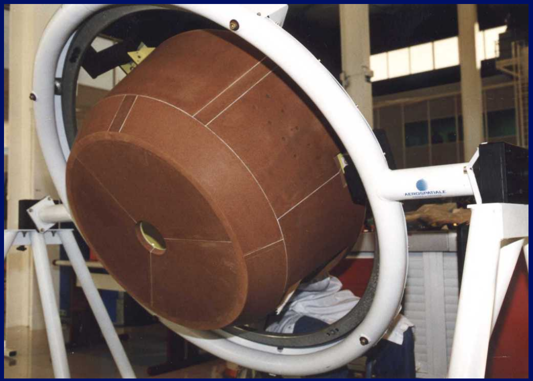
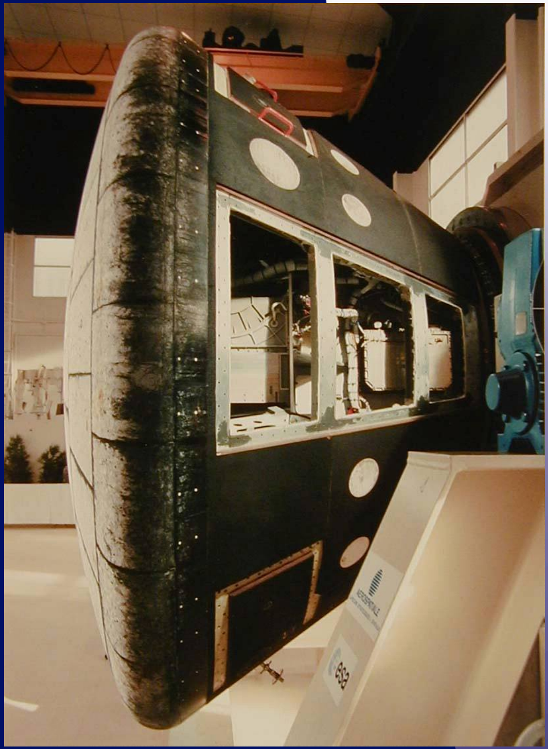
Norcoat-Liege heritage
ARD cone & back-cover





- Panels 19 mm thick
- Implementation of many singularities
  - thrusters, TPS experiments, measurement devices, antennas, access doors, etc…
- Successful flight on October 21st 1998
- Very nice aspect after recovery

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Norcoat-Liege heritage
BEAGLE 2 Frontshield & back-cover

- 31 tiles on Frontshield
  - 9 mm, 3.9 kg total mass (< 4.5 kg/m²)
- tiles + several singularities on Back-Cover
  - 3 to 6 mm, 2.0 kg total mass (< 2.5 kg/m²)
- Very late design modifications implemented

Norcoat-Liege adaptation to Mars missions

- Outgassing : elaboration of appropriate thermal treatment
  - Selection of optimal : Temperature, Vacuum level, Duration
- Stringent cleanliness conditions to meet decontamination / sterilisation requirements (planetary protection regulations)
  - Screening and selection of appropriate method based on medical experience
  - Two different processes established for FS & BC
- Dust erosion (joined CEA-CESTA / EADS-ST approach)
  - Modelling
  - Test facilities

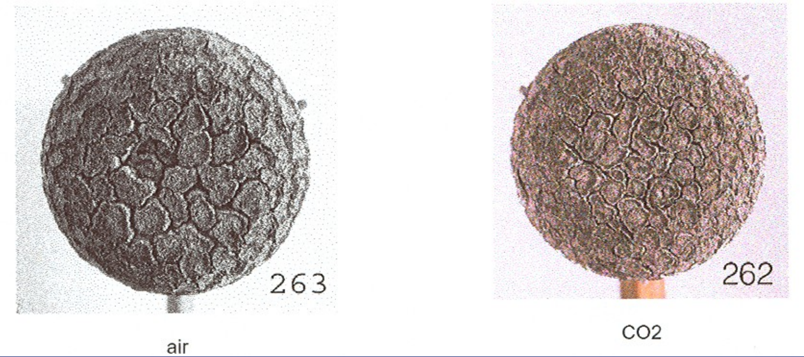
Bonding in class 100 room of sterilised tiles for Beagle2 back-cover

Norcoat-Liege Qualification for Mars Missions (1)
Stagnation point tests

- IPM Russia
  - Air and CO_2
  - Up to ~1100 kW/m²
- COMETE
  - Air ; up to ~2000 kW/m²
- VKI Belgium
  - Comparison Air / CO_2
  - Up to ~2000 kW/m²

→ Very good behaviour

→ No noticeable difference under air or CO_2



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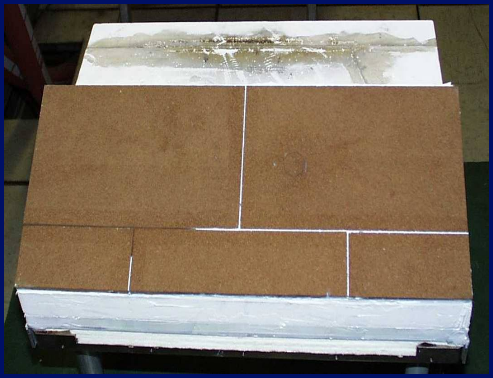
Norcoat-Liege Qualification for Mars Missions (2)
Tangential flow tests - EADS-ST SIMOUN facility

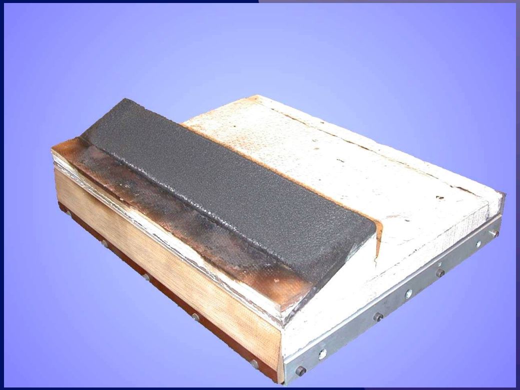
EADS SPACE TRANSPORTATION

- BEAGLE 2
  - CO_2
  - Up to ~800 kW/m²
- NETLANDER
  - Air
  - up to ~1800 kW/m²



→ Very good behaviour of the whole arrangement (including joints, steps & gaps)

→ Capability of the material certainly significantly higher than the experienced test results (limited to required values)



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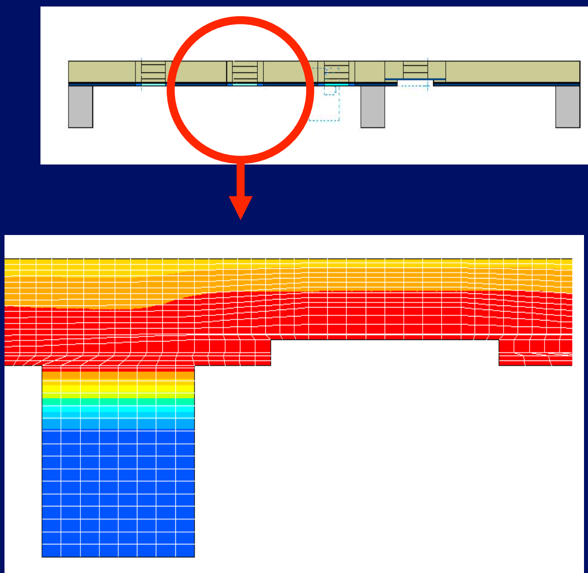
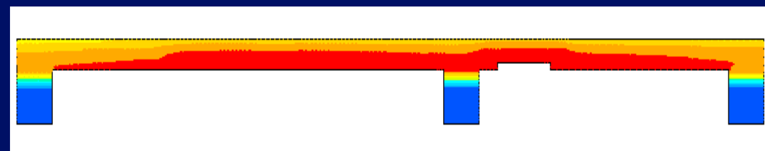
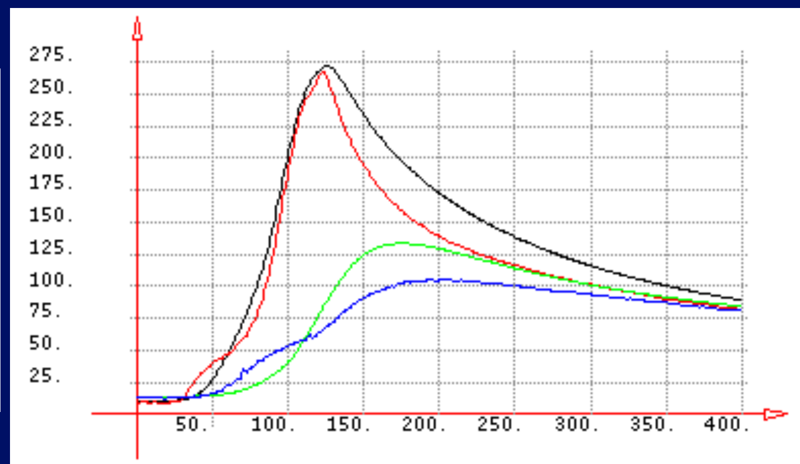
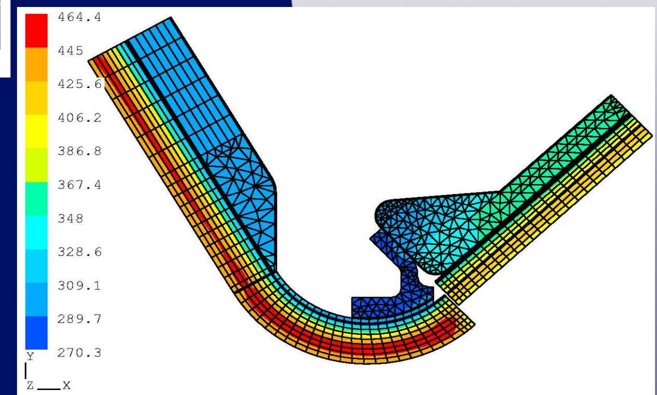
Test exploitation & determination of material thermal characteristics (Beagle2)



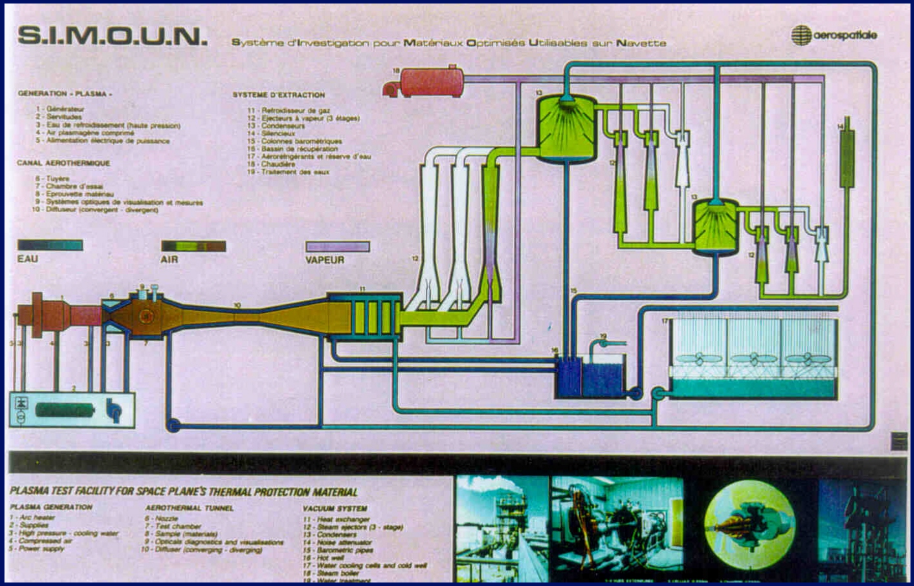


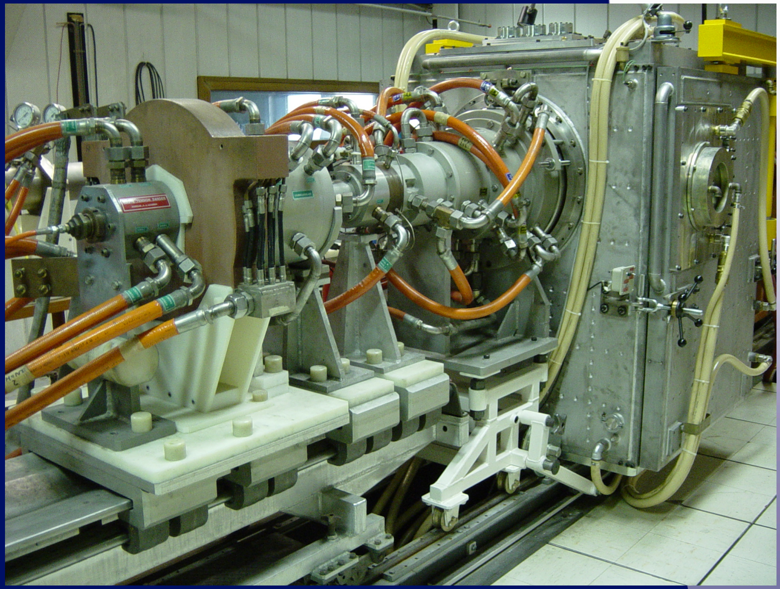




- AMARYLLIS 2D model, with pyrolysis and surface recession
- iterative process to optimise the restitution of measured temperatures, compared to computed ones.
- Elaboration of material thermal model, including ablation and pyrolysis phenomena

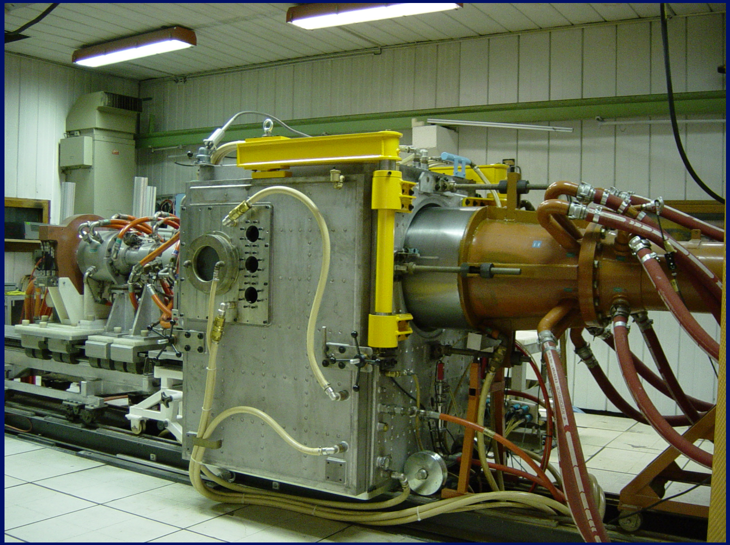
SIMOUN facility overview

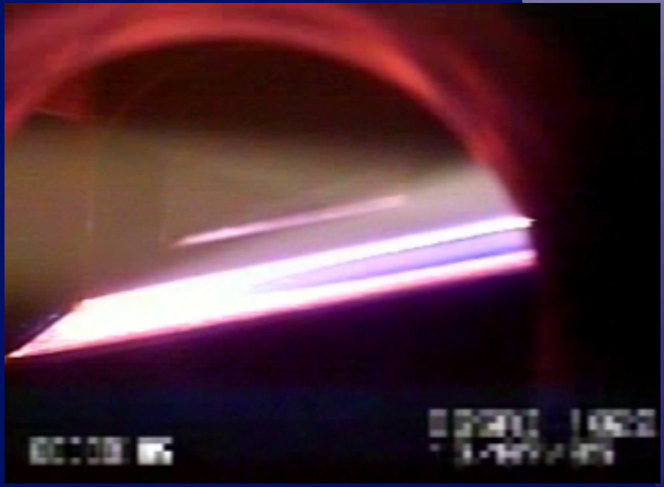




SIMOUN SET UP :

- Generator
- Test chamber
- Vacuum system
- Sample in flow





SIMOUN
Main Characteristics

POWER	6 MW
STAGNATION PRESSURE	1 TO 18 BAR
STAGNATION ENTHALPY	4 TO 14 MJ/Kg(air)
FLOW	air, N_2, CO_2
RUN TIME	a few sec. to 30 min.

STAGNATION POINT

NOZZLE : Contoured, Mach number 4.5

SAMPLE : Diameter 50 mm

Pressure : 50 to 200 mbar

Heat flux : 700 to 2500 kW/m^2 *

Extended field :

Pressure : 200 to 500 mbar

Heat flux : 2500 to 4000kW/m^2

For tests duration <1mn : up to 6000kW/m^2 expected (still to validate)

* : cold wall conditions

FLAT PLATE & WEDGE

NOZZLE : Superelliptic, Mach number 5

SAMPLE : 300 x 300 mm^2 , 150 mm thick

Angle of attack : 0 to 16°

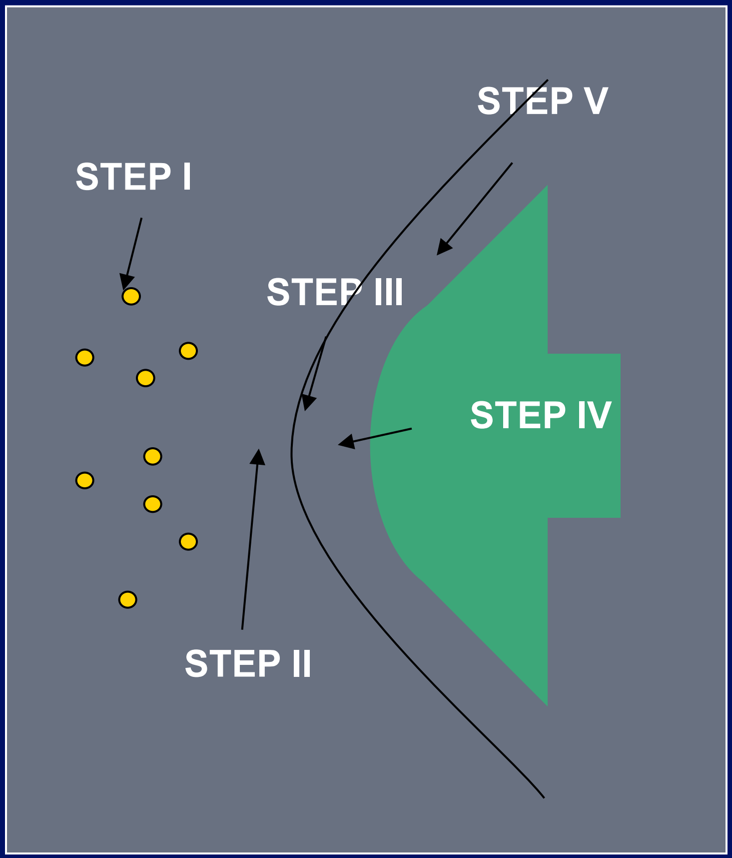
Pressure : 3 to 180 mbar

Heat flux : 20 to 1600 kW/m^2 *

For tests duration <1mn : up to 2000kW/m^2 expected (still to validate)

* : cold wall conditions

Dust erosion
Phenomenon and Methodology Overview



Step I : particles description
- ✓ Nature and size
- ✓ Distribution versus altitude
- ✓ Particles velocity

Step II : shock particles interaction
- ✓ Particles modification (break up)
- ✓ Flow perturbation

Step III : shock layer crossing
- ✓ Particles deceleration, deviation and heating

Step IV : particles TPS interaction
- ✓ TPS erosion
- ✓ Heat fluxes increase on TPS : due to wall roughening and earlier transition to turbulence

Step V : debris
- ✓ Effects on the boundary layer
- ✓ « Debris shielding »

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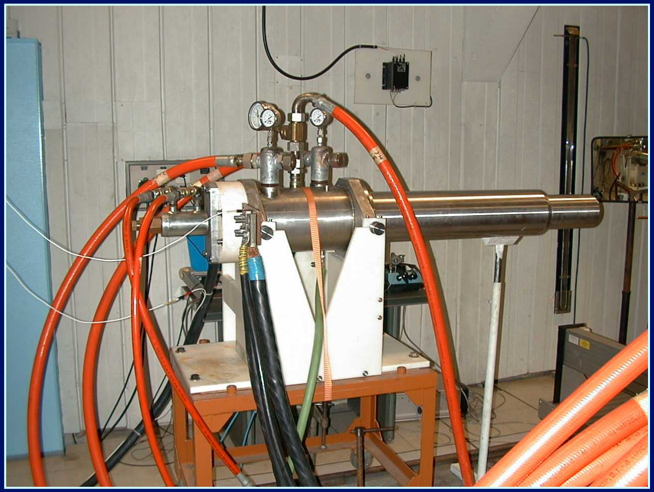
Test facilities
AQTIL

- Study of alumina particles impact on Ariane 5 (due to boosters separation rockets)
- Adaptation of existing plasma torch
- Development of specific injection device
- Implementation of several diagnostic techniques for control of particles seeding
  - Velocity
  - Homogeneity
  - State (solid or melt)

→ facility is now available and fully qualified for TPS characterisation under particles impingement



EADS SPACE TRANSPORTATION

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SIMOUN
Adaptation for particle injection

- Application on SIMOUN of the same methodology as on AQTIL :
  - Nozzle exit particle injection
  - Specific diagnostics

- To be validated in :
  - Low ambient pressure
  - Supersonic flow

- First step : Stagnation point (in 3rd quarter 2006)

- Then, implementation completed for plane board tests

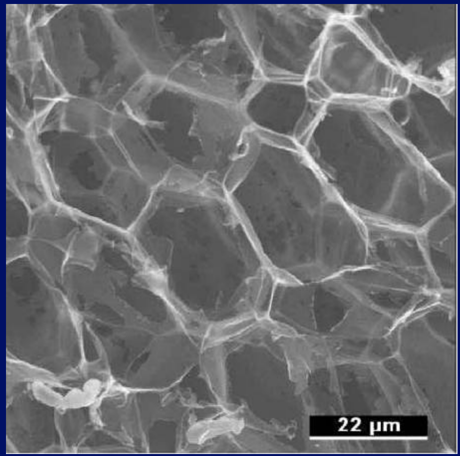
R & D approach

- Detailed characterisation work performed during the past years
- In association with local Research Centers (CNRS, CRPP)

- Influence of main molecules constituting the material
- Analysis of degradation process

→ Very interesting results, especially wrt stability at high temperature

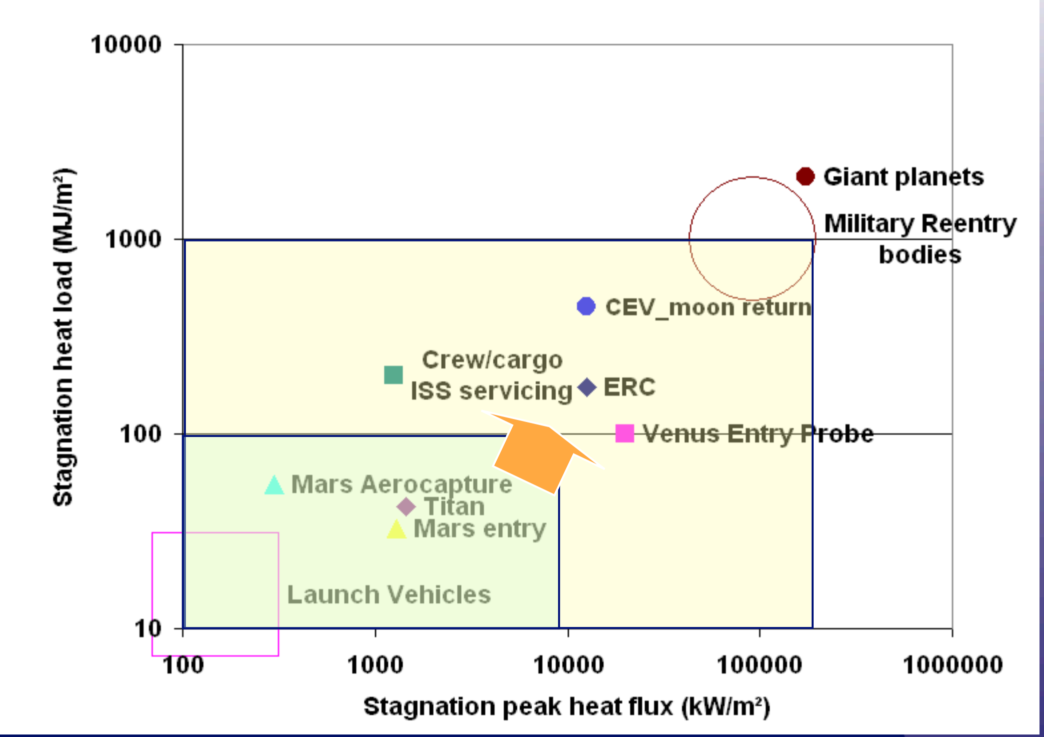
→ Basis for thorough understanding and future improvements



Norcoat-Liege after carbonization @ 2000°C

Growth potential

- Better comprehension of the role of each constitutive molecule
  → basis for a more detailed theoretical modeling
  →enables future tailored improvements of the material.
- Two attractive perspectives to enlarge the use of this type of material to a wider domain.
  - Inclusion of a mechanical reinforcement in the material, in order to strengthen the char layer.
  - Search for a lightened material, in view of application on aft body of entry probes



Conclusion

- EADS-ST ready to bring a significant contribution to ExoMars development and future success
  - Thermal protection
  - Qualification facilities
  - More generally, all the disciplines required for atmospheric entry (AED, ATD,…)

- These technologies and techniques can obviously also serve any future scientific mission with atmospheric entry probe

Thank you for attention

Any questions ?